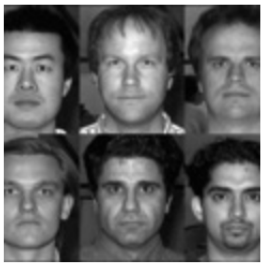
Homework 5 **CSCE 421**
Due: 7.00pm on December 4, 2019

Instructions for homework submission
Please submit on eCampus a **single pdf** file containing your solutions.
a) **Form teams of 5 classmates!**
b) Work with your teammates toward this project.
c) With your team, you will present your work as an e-poster in the last class (Dec. 4th).
d) Please write a final report and hand this out along with your poster presentation (printed in regular size paper). At the end of the pdf file, please include your code.
e) Please start early :)

Question: Machine learning for facial recognition
In this problem, we will process face images coming from the Yale Face Dataset, uploaded under the *Homework5_YaleDataset* folder in the Google Drive. This dataset contains images from 15 individuals. For each individual there are 11 images taken under a variety of conditions e.g., displaying a happy expression, wearing glasses etc. The goal of this problem is to perform the following three tasks:

1. face recognition (i.e., classification of 15 individuals)
2. emotion recognition (i.e., sad, happy, surprised, normal)
3. wearing glasses or no glasses



(a) (1 point) Data pre-processing. Resize the input images to a final size of 30×30. Then append all columns of each image into a vector with final size 1×900.

(b) (3 points) Principal Component Analysis (PCA). In this part you will use PCA to reduce the dimensionality of the original images and perform the target classification tasks.

(b.i) (0.5 points) Implement PCA on the input images. Assume that the input vector of PCA contains all rows of an image stacked one on top of the other. You can use available libraries that calculate the eigenvalues and eigenvectors of a matrix. *Hint:* Don't forget to normalize the data.

(b.ii) (0.5 points) Plot a curve displaying the first k eigenvalues $\lambda_1, \ldots, \lambda_K$, i.e. the energy of the first K principal components. How many components do we need to capture 99% of the energy?

(b.iii) (0.5 points) Plot the top 10 *eigenfaces*, i.e. the eigenvectors $\mathbf{u_k}$, $k = 1, \ldots, 10$ obtained by the PCA.

(b.iv) (0.5 points) Select a couple of images from the data. Use the first k eigenfaces as a basis to reconstruct the images. Visualize the reconstructed images using 1, 10, 20, 30, 40, 50 components. How many components do we need to achieve a visually good result?
Hint: Reconstruction of an input vector $\mathbf{x}$ based on the eigenvectors $\mathbf{u_1}, \ldots, \mathbf{u_K}$ is given by the following expression $\mathbf{x} \approx \mathbf{x_0} + \sum_{k=1}^{K} c_k \mathbf{u_k}$, where $c_k = \mathbf{u_k}^T \mathbf{x}$ is the projection of the input image to the k^{th} eigenvector.

(b.v) (1 point) Split the input data into training and testing *making sure that every person is included in each set.* Use any of the classification methods that we have learnt so far to perform the three target classification tasks. Use as input features the coefficients c_k corresponding to the first eigenvectors of PCA. Experiment with different number of dimensionality through a 5-fold cross-validation and report the average recognition accuracy over all folds.

(c) (3 points) Image classification with CNNs: In this part, you will use a CNN to perform the three classification tasks.

(c.i) (1 point) Use a CNN to perform the three target classification tasks. Use the same split for the train and test set as in Question b. Experiment with different CNN parameters, e.g. # layers, filter size, stride size, activation function, dropout, pool size, etc. Report running time for training the CNNs.

(c.ii) (1 point) Data augmentation is a way to increase the size of our dataset and reduce overfitting, especially when we use complicated models with many parameters to learn. Using any available toolbox or your own code, implement some of these techniques and augment the original Yale Face Dataset.
Hint: You can find more information in *hw3_DataAugmentationUsingDeepLearning.pdf* from *Homework 3* folder on Piazza and in the following link:
`https://machinelearningmastery.com/image-augmentation-deep-learning-keras/`

(c.iii) (1 point) Implement a multi-task CNN to jointly perform the three classification tasks. Report the final classification results of the three tasks, as well as the average running time.

(d) (3 points) In-class presentation. You will present your methodology and results as an e-poster in class of Dec. 4th. **All members of the team need to be present for their poster presentation.**

(d.i) (2 points) Collect your results and create a poster presentation of your work. The e-poster will give the main gist of your work, including the problem statement, your methodology, and the main results from your experiments. **Add visuals to your poster so that people understand the main concepts.** You can find here the link to prepare your poster presentation `https://www.youtube.com/watch?v=1RwJbhkCA58&feature=youtu.be`.

(d.i) (1 point) During the class, half of your team will be next to the poster, the other half will go around the other posters and write up the main findings of the other teams. Then the two parts of each team will interchange. The grade of this question will be given from the class participation.